2 Comparison with ISWS Data

Field Data Description

General. The ISWS collected velocity, water-level, and suspended sediment data before, during, and after vessel passage at 2 sites on the Illinois Waterway and 3 sites on the Mississippi River between 1989 and 1995 (Bhowmik et al. , 1998). Velocity data were collected with electromagnetic velocity meters and recorded at a rate of 1 sample/sec. An 11 second moving average was used to smooth the velocity data before extracting the return velocity from the time history of velocity. The water level data were collected with a wave gage manufactured at the ISWS and were recorded at a rate of 10 samples/sec. No mention was made in the Bhowmik et al (1998) regarding any smoothing or moving average of the water level data before the drawdown was extracted from the time history of water level. Details of the three sites used in this analysis (the other two were used in Maynord, 1996b) are shown in Table 1.

Table 1. Details of ISWS Field Sites from Bhowmik et al (1998)

Site/river	Date(s)	Average Ambient Vel, m/sec	Channel top width, m	Average Depth, m	# of Tows	# of Working Velocity Meters
McEver's Island/ Illinois	5/15/89-5/19/89	0.27	230	3.37	12	5
Apple River/ Mississippi	5/14/95-5/25/95	0.81	400	5.16	25	7
Goose Island trip 1/ Mississippi	8/20/90-8/29/90	1.13	418	6.04	15	8
Goose Island trip 2/ Mississippi	7/15/91-7/25/91	0.83	403	5.49	37	13

Data collected by the ISWS appear to be accurate in spite of the difficulty in collecting this type of data. Return velocity data are almost certain to exhibit considerable scatter. Velocity meters are placed in an environment where it is difficult to insure consistency because of debris moving down the river or external electronic interference. Separation of tow influence from ambient conditions is always a challenge because the ambient stage and velocity in the river vary over time scale of a tow event. Maynord and Martin (1998) examined variations in ambient velocity prior to passage of a tow and found that the ambient velocity, after removing short period turbulent fluctuations, varies +- 15 percent about the mean ambient velocity during a 100 sec time period which is comparable to the passage time for a tow. Combination of the various sources of error leads to significant variability in the measured data. The only criticisms of the data collected by the ISWS was the lack of electronic recording wave gages at McEver's Island site that were used at the other sites, the need for a greater period of water level measurement before the tow arrived, and the use of only one wave gage.

The field data from the three ISWS sites were screened first to eliminate data not meeting the requirements for blockage ratio being less than 85 and tow length being greater than 40 percent of the channel width. The ISWS collected tow event data for any tow passing the site during the observation period. Many of the tows for which data were collected were small or unloaded and produced return velocity or drawdown that could not be discerned from the ambient fluctuations. This initial screening reduces the data set to the largest tows which are the tows having the most impact on the waterway. This is important because the tow impact can only be extracted from the data record if the impact is significantly greater than the ambient fluctuations. The tow event data that were eliminated were generally tows that produced effects that were so small the effect could not be discerned from the ambient fluctuations.

A second screening was done to eliminate mixed tows which can be difficult to accurately define the vessels effective cross-sectional area and length. This basically reduced the data set to 2- or 3-wide by 3-, 4-, or 5-long tows with all barges having the same draft. The next screening was done to eliminate velocity meters that appeared unreliable or those which were less than one vessel width away from the vessel centerline. Reliability was determined herein based on how the ambient velocity from a meter compared to its neighboring velocity meters. The argument behind rejecting velocity meters based on ambient velocity is that if a meter can not provide a reliable estimate of ambient velocity, that meter can provide no useful information. All return velocity data were taken directly from the ISWS reports which used a 11 sec moving average to determine the maximum return velocity. Although the final data set was greatly reduced from the original number of tows, the data set was adequate to evaluate the NAVEFF model since the model is primarily based on physical laws rather than purely regression. As stated before, the majority of tows removed from the data set were small or unloaded tows that produce tow effects that are difficult to extract from normal variations in the ambient conditions.

The final screening was conducted regarding the drawdown data. Only data based on an electronic recording wave gage were used in the analysis. The original data files were obtained from the ISWS and a 11 second moving average was used to smooth the data just as the ISWS used an 11 sec moving average with the return velocity data. This smoothing removes short period wave activity and any electronic variations that are not part of the tow induced drawdown process. Staff gage data were not used because it was not known whether the staff gage values reflected only drawdown or drawdown plus any short period wave activity. The maximum drawdown resulting from the smoothing process was often less than the drawdown reported in the ISWS reports. The fact that the 11 sec moving average drawdown values are less than the drawdown values in the ISWS reports suggest to this author that a portion of the ISWS drawdown values can not be attributed to vessel induced drawdown because drawdown is a long period event. The quoted accuracy of the wave gages in the ISWS reports was 0.015 m which is 59% of the average of all drawdowns shown in the following paragraphs. The Apple River experiments and both Goose Island Experiments had only one electronic recording wave gage whereas the McEvers Island experiments had a staff gage. The manner in which these screening efforts affected the individual sites are presented in the following paragraphs.

Apple River Island on Mississippi River. Screening of the 25 tows from Bhowmik et al (1994b) resulted in the use of the following tows. Drawdown from the smoothing process is shown if a recording wave gage was used. The other pertinent data can be found in the ISWS report.

Cooperative Ambassador, drawdown not analyzed because staff gage used
Christine Bailey, drawdown not analyzed because staff gage used
Herman Pott, drawdown not analyzed because staff gage used
Dell Butcher, 0.027 m
T.S. Kunsman, 0.040 m
Trojan, 0.012 m
Cooperative Mariner, 0.067 m

One of the seven working velocity meters, MMB527/332 (Marsh McBirney Model #527, serial number 332) was rejected because the ambient velocity was about 64 percent of two adjacent velocity meters.

Goose Island on the Mississippi River Trip 1. Screening of the 15 tows from Bhowmik et al (1994c) resulted in the use of the following tows. Drawdown from the smoothing process is shown if a recording wave gage was used. The other pertinent data can be found in the ISWS report.

Sierra Dawn, data not available
Dell Butcher, 0.020 m
Dare Carlton, data not available
T.R. Beesber, 0.053 m
Kevin Michael, 0.021 m
Twin City, 0.041 m

None of the 8 working velocity meters from trip 1 were rejected.

Goose Island on the Mississippi River Trip 2. Screening of the 37 tows from Bhowmik et al (1994c) resulted in the use of the following tows. Drawdown from the smoothing process is shown if a recording wave gage was used. The other pertinent data can be found in the ISWS report.

Ardyce Randall, 0.020 m
Scarlet Knight, 0.021 m
James F. Neal, 0.030 m
Frank T. Heffelfinger(1), data not available
Queen City, data not available
Helen M Clements(2), 0.015 m
Frank T. Heffelfinger(2), 0.024 m
Conti-Karla, 0.033 m

Cooperative Mariner, 0.026 m
Hornet, 0.034 m
Sam M. Fleming, 0.041 m
Kevin Michael, 0.024 m
A.M. Thompson, 0.027 m
Badger, data not available
Dell Butcher, 0.025 m

None of the 13 working velocity meters from trip 2 were rejected.

McEvers Island on the Illinois River. Screening of the 12 tows from Bhowmik et al (1994a) resulted in the use of the following tows. No drawdown data were used because all tests used a staff gage for measurement of water level.

R.W. Naye
Mobil Leader
Cooperative Vanguard
Marvin Norman
Illini
Thurston B. Morton
Clarence G. Frame

Two of the five working meters were rejected. Meter MMB511/1000 (0.91 m above bed) was rejected because it had an ambient velocity which was about 60 percent of meter MMB511/999. Meter MMB 511/999 was placed directly below the rejected meter at 0.15 m above the bed. Meter S4/071(0.91 m above bed) was rejected because it was the meter farthest from the bank yet had an ambient velocity of only 16 percent of the average channel velocity. The magnitudes of the rejected meters would indicate that either they were not operating properly or there was some local phenomenon, such as an upstream bathymetry feature, affecting the output. One would not expect a one-dimensional approach like NAVEFF to predict correct magnitudes where local conditions introduce abnormalities.

Results

Apple River Island on Mississippi River. Results for return velocity for each of the 7 tow events are shown on Figures 1 and 2. A scatterplot of all return velocity data is shown in Figure 3. The MRE is 0.53 and the MTE is 0.37. Results for drawdown for the 4 tow events having drawdown data are shown in the Figure 4 scatterplot. The MRE and MTE are 0.69.

Goose Island Trip 1 on Mississippi River. Results for return velocity for each of the 6 tow events are shown on Figures 5 and 6. A scatterplot of all return velocity data is shown in Figure 7. The MRE is 0.38 and the MTE is 0.21. Results for drawdown for the 4 tow events having drawdown data are shown in the Figure 8 scatterplot. The MRE is 0.30 and the MTE is 0.003.

Goose Island Trip 2 on Mississippi River. Results for return velocity for each of the 15 tow events are shown on Figures 9-12. A scatterplot of all return velocity data is shown in Figure 13. The MRE is 0.51 and the MTE is 0.33. Results for drawdown for the 12 tow events having drawdown data are shown in the Figure 14 scatterplot. The MRE is 0.47 and the MTE is 0.44.

McEvers Island on Illinois River. Results for return velocity for each of the 7 tow events are shown on Figures 15 and 16. A scatterplot of all return velocity data is shown in Figure 17. The MRE is 0.35 and the MTE is 0.02. No wave gage drawdown data were available for McEvers Island.

Error Measures for All Data. Combining all ISWS return velocity data resulted in a MRE of 0.48 and a MTE of 0.29. Combining all ISWS drawdown data resulted in a MRE of 0.48 and a MTE of 0.40.

Exponential Decay Function

The Goose Island Trip 1 and 2 data provide the best field data to evaluate the shape of the exponential decay function for return velocity because eight velocity meters were spaced over about 220 m on one side of the waterway. Based on the plots of return velocity versus distance from vessel for each tow shown in Figure 5-6 and 9-12, the exponential decay function provides a good fit of the data.

Data Variability

As shown in the scatterplots and the values of MRE and MTE, there is significant scatter in the observed versus computed values. A portion of this scatter is due to the fact that NAVEFF does not account for many factors that could affect the prediction that were not included in the model. For example, the rake angle of the bow of the barges is difficult to obtain while taking field measurements. In developing NAVEFF it was assumed that this angle did not vary enough to warrant it's inclusion in NAVEFF. The one-dimensional formulation of NAVEFF means that a single cross section is used to describe the waterway whereas local variations in bathymetry could have an impact on measured return velocity. Vessels skewed only a few degrees relative to the channel axis could have an effective beam greater than the actual beam of the vessel. The writer believes that one of the main sources of scatter between observed and computed return velocity and drawdown is the difficulty in extracting the tow influence from the fluctuating ambient velocity or water level. The stage and ambient velocity in the river has fluctuations occurring at the same relatively low frequency as the tow. This makes it almost impossible to extract only the tow influence.

To analyze the data variability, the Goose Island Trip 2 data were analyzed for consistency of return velocity from tow events that should have resulted in similar values because of their similar size, draft, length, and position in the channel. Thirteen tows were 3X5, loaded, downbound, and traveling at about the same position in the river, with the sailing line varying from 49-101 m (160-330 ft) from the right bank in a channel about 400 m (1300 ft) wide. Thirteen velocity meters were used in the Goose Island Trip 2 tests. Only eight of the thirteen velocity meters had enough data (7 or more tow events) to conduct the analysis.

The primary difference between these thirteen tows was their speed which varied from 2.6 to 3.9 m/sec (8.4 to 12.8 ft/sec). The return velocity from each of the thirteen tows had to be normalized to make the thirteen tows comparable. The differences in tow speed were normalized by multiplying the maximum observed return velocity at each velocity meter by the ratio of the computed average return velocity from Jansen and Schijf (1953) for the Queen City tow to the computed return velocity for the given tow. The Queen City was chosen because it was the tow having speed closest to the average speed of the thirteen tows. This normalization converted all the observed maximum return velocities to the Queen City vessel speed which was 3.3 m/sec. The normalized maximum return velocity is shown in Table 2. To insure understanding of the normalization process, two examples are given. In example 1, the maximum return velocities (normalized) in Table 2 for the Queen City are the same actual return velocities as plotted in Figure 10 since the Queen City was the basis for the normalization and return velocities were not affected. In example 2, since the speed of the Ardyce Randall (2.9 m/sec) was less than the Queen City (3.3 m/sec), the Ardyce Randall return velocities had to be increased to be comparable to Queen City. The maximum return velocities (normalized) in Table 2 for the Ardyce Randall differ from Figure 9 actual return velocities by the ratio of the computed return velocities shown in Table 2, column 2, or 0.175/0.142 = 1.23. Meter M834, which is the Table 2 and Figure 9 velocity meter closest to the tow, has the highest actual return velocity near the tow of about 0.233 m/sec as shown in Figure 9. The corresponding value in Table 2 has a value of 0.233*1.23 = 0.287 m/sec.

Since the tows were similar and speeds were normalized, the maximum return velocity should be constant for a given velocity meter. The last three rows are the mean normalized return velocity, the standard deviation, and the standard deviation/ mean which is sometimes called the coefficient of variation (CV). Results show that the average CV for the 8 velocity meters is 34 percent. Under the best conditions of a single velocity meter placed and not moved and relatively constant flow rate, significant scatter exists in the data. This finding is not a criticism of the ISWS data collection but shows how difficult it is to obtain consistent tow effects data. This author expects any return velocity data set to show similar variability.